Neural Network-Based Hyperspectral Algorithms

Walter F. Smith, Jr. and Juanita Sandidge
Naval Research Laboratory
Code 7340, Bldg 1105
Stennis Space Center, MS
Phone (228) 688-5446 fax (228) 688-4149 email; wsmith@nrlssc.navy.mil
Grant Number: N0001499WX30272

LONG TERM GOAL

The long-term goal of our effort is development of robust numerical inversion algorithms, which will retrieve inherent optical properties of the water column as well as depth, and bottom type information from remotely sensed hyperspectral data sets of littoral regions.

OBJECTIVES

We have two primary objectives; 1) using a combination of in-situ and model data of water column variables (IOP's, depth, bottom type, upwelling radiance, etc.) a neural network non-linear function approximation model will be used to establish the inverse relationship between upwelling surface radiance and the water column variables, 2) validate the resulting inversion algorithms with in-situ data and provide estimates of the error bounds associated with the inversion algorithm.

APPROACH

The paradigm selected for developing relationships between IOPs, bottom reflectance, depth, and high resolution spectral radiance is the neural network (Lippman, 1987). Neural network-based algorithms have been demonstrated by the investigators for retrieval of water depth from Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) imagery. Likewise, investigators at the Naval Research Laboratory (NRL) have applied neural network-based algorithms for retrieval of absorption and scattering coefficients from Hyperspectral Digital Imagery Collection Experiment (HYDICE) and other hyperspectral systems. These initial demonstrations showed promise, but the work needs to be put on a more solid scientific/statistical foundation. Many important questions are unanswered. Can universal algorithms be developed which work well for many water and bottom types? How many spectral bands and which wavelengths are optimal for these retrievals? What are the environmental factors that most adversely effect retrieval accuracy, *i.e.*, when and where will it work best, and what are the error bars on retrievals of this type? The proposed approach will utilize airborne hyperspectral and coincident ground truth data from existing field programs (COPE, CoBOP, NAVO blind tests, etc.), existing RTE models (HYDROLIGHT and MODTRAN), and neural network paradigms to develop and characterize relationships between spectral radiance, depth, IOPs, and bottom type. Error and sensitivity analysis will be conducted to better understand the physical basis of observed empirical relationships.

In summary, our research seeks to utilize existing and yet to be collected hyperspectral imagery and ground truth data sets (COPE, CoBOP, HYMSMO, NAVO blind tests, etc.), and the existing radiative

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **Neural Network-Based Hyperspectral Algorithms**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Code 7340, Bldg 1105,Stennis Space Center,MS,39529**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

transfer models, HYDROLIGHT and MODTRAN, to produce a diverse mixture of field and simulated data. This data will be the basis for development of neural network algorithms to characterize the relationships between the relevant parameters. Trained neural models will evolve into remote sensing algorithms for the HRST sensor. The training process will be accomplished on a specially constructed hybrid neural network, which uses both stochastic as well as deterministic optimization techniques. Resulting algorithms will be characterized in terms of their expected performance and limitations.

WORK COMPLETED

FY99 Objectives

1. NRL personnel will gather existing *in situ* data, run the HYDROLIGHT and MODTRAN models and conduct the validations required to build the database for the analysis proposed here. NRL has a 58 ft coastal research vessel and extensive ocean optics instrumentation, which will be utilized jointly with USM investigators for participation in NEMO cal./val. experiments in the Gulf of Mexico. In collaboration with USM appropriate neural network architectures and learning algorithms (deterministic, stochastic, hybrid, self-organizing) will be evaluated, coded, and tested. **Completed--***NRL has gathered numerous in-situ AC9 and HISTAR data sets from a variety of previous and ongoing experiments. The Tampa '98 HISTAR data collected by NRL has been used in the HYDROLIGHT Model runs conducted by USM to construct an initial data set for inversion. USM and NRL to construct neural inversion models have used the HYDROLIGHT model data.*

2. A multivariate database of spectral radiance, depth, IOPs, and bottom types will be created from in situ and model data so that analysis of the multivariate relationships can be characterized leading to improved scientific/statistical understanding. Relevant questions such as the universality of relationships, required number and spectral placement of channels, etc. will be investigated. **Completed--***Utilizing NRL's 58 foot research vessel we conducted a high resolution bathymetric survey in the Lido Key area. Included in the survey were numerous optic stations where AC9 and ASD data was collected. This survey was coincident with an AVIRIS overflight. The AVIRS data will be included in the training and validation effort when it is received. The collected data along with the resulting model runs will be used with the AVIRIS overflight data to determine the depth and IOP characteristics of the Lido Key area.*

3. The principal investigator (WFS) will participate in NEMO cal./val. activities. **Completed--***NRL investigators plan to participate in future Tampa collection efforts and will use a new 65' R/V recently acquired to acquire additional optical and bathymetric data sets.*

4. Prototype neural network-based bathymetry, IOP, and bottom type algorithms will be developed based on an NRL developed unique hybrid artificial neural network that has been used to successfully recover IOPs for Case II water. **Completed**—NRL is using a hybrid neural network approach developed under a previous research effort. The network has been used to construct an approximation between the USM generated upwelling radiance from HYDROLIGHT (populated with NRL HISTAR data) and the depths and bottom types used to generate various upwelling spectral radiance values.

RESULTS

The bathymetric survey (see Figure 1) conducted by NRL in May, 1999 in the vicinity of Lido Key and Crescent Beach, has been post-processed and is available on the NRL Code 7342 web site. The survey areas were selected in conjunction with Dr. Curtiss Davis. The areas are typical of the Tampa/Sarasota region, with gentle sloping sandy bottoms and a small number of distinctive features (holes or ridges).

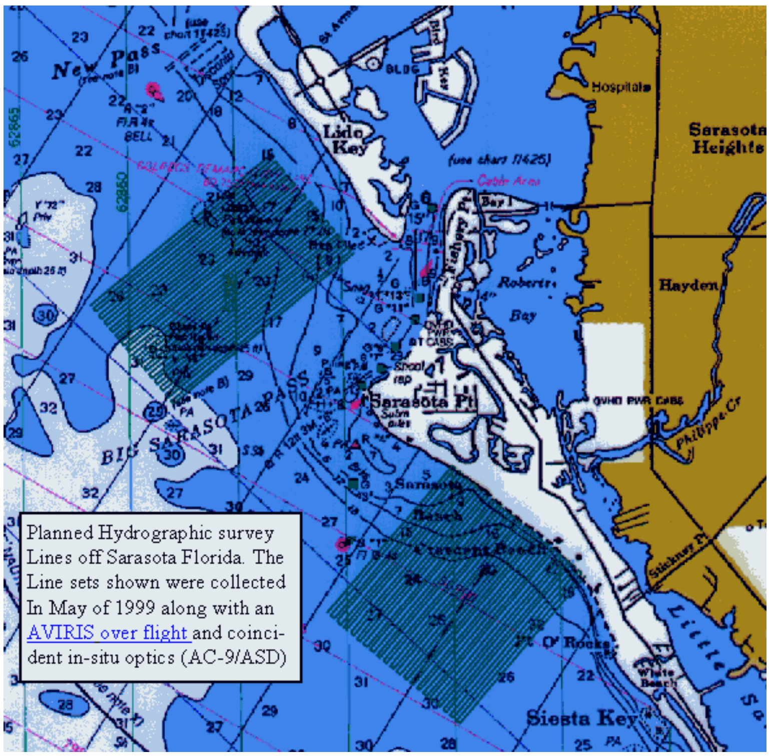

Figure 1. Survey regions for coincident hyperspectral and bathymetry surveys.

Figures 2 and 3 show the survey tracks associated with the Lido Key and Crescent Breach region and the tide corrected depths. The bottom was primarily sand with some sparse vegetation. This data has not been included in a training set to date.

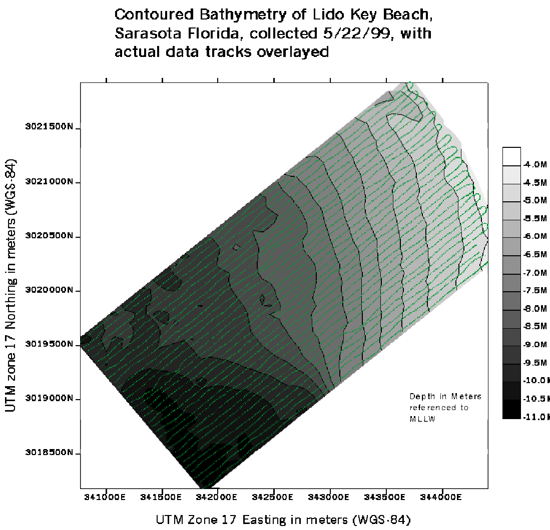

Figure 2. Lido Key Survey Lines and Depths

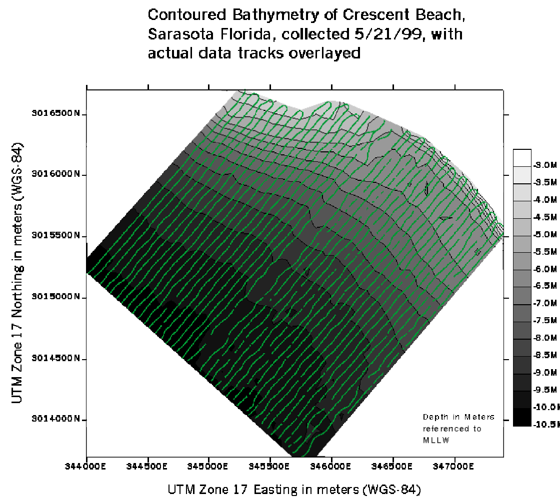

Figure 3. Cresecent Beach Survey Lines and Depth

An AVIRIS overflight (See Figure 4) was also collected coincident to the bathymetric survey and optics data collection. Unfortunately, the coincident overflight region only fully covers the Lido Key

Figure 4. AVIRIS Overflight Quicklook

region. We are currently awaiting the full AVIRIS data set. Upon receipt of the hyperspectral data we plan to train a neural network for this region and compare the results with our HYDROLIGHT model version output.

We are currently using a data set constructed by USM from the HYDROLIGHT model, and the October ’98 Tampa Bay HISTAR data. The resulting data set was used as the neural network training set. The training set consists of five inputs and one output. The inputs correspond to the first five principal components of the spectral remote sensing reflectance representing 99.69% of the variance in the data set and the corresponding water depth as the output. The data set is representative of numerous bottom types, water types, and sun angles. The hybrid neural network was capable of converging to a solution, which had a RMS error of 1.6m for the entire data set and a RMS error of 1.1m for depths less than 4m. The result is not as good as the result reported by USM, which had a RMS error of .31m for depths less than 4m using a Levenburg-Marquardt network for training.

IMPACT

Our initial results are promising and indicative of good progress toward producing an algorithm capable of retrieving such water characteristics as depth, visibility, bottom type, etc. Efforts in the near term are focused on incorporating inherent optical properties and bottom types into the training algorithm.

TRANSITIONS

The bathymetry and optics data from the May, 1999 Sarasota collection are available to other HYCODE investigators.

RELATED PROJECTS

All work to date has been done in conjunction with a similar effort underway by Dr. Ron Holyer of USM. The USM team has produced the initial data set with the assistance of NRL and Dr. Holyer has conducted the variance analysis of the data, which NRL investigators have made use of in building neural network training set. Continued close collaboration between the two groups is planned. The collaboration draws on the strengths of both organizations and has been quite successful to date.

REFERENCES

Smith, Walter F. Jr., May 1999, Neural Network Solutions to the Ocean Optics Inverse Problem, Dissertation, University of Southern Mississippi.